Chapter 4
Description of Locks and General Terms

4-1. General

This chapter introduces types of locks and common design terms that are used in a navigation lock project. The types of locks presented in this chapter are composed of mass concrete, reinforced concrete, tied-back concrete, steel sheet piling, and earth (chamber walls) construction. Other less common types of locks such as articulated frame have been constructed but are not discussed in this manual. The lock components introduced in this chapter include lock chamber monoliths, upper and lower gate bay monoliths, culvert valve monoliths, culvert intake and discharge monoliths, approach walls, lock sills, and lock floors. Chapter 5 provides details on the design and layout of these components. The major components of a lock are designated on Plates 6 and 7; the terms indicated on these plates will be used throughout this manual. An isometric presentation of a single lock adjacent to a gated spillway is shown on Plate 8. This chapter also includes plates which contain typical details and data that will assist in preliminary proportioning of lock structures. Most locks in the United States are made of concrete. The resistance of concrete to impact, abrasion, and deterioration and its relatively low cost to construct and maintain are the qualities which make this material the most suitable for long-life navigation structures. Depictions of projects with various size, configuration, and number of locks are shown on Plates 9 through 14.

4-2. Mass Concrete

The mass-concrete-type lock, as the name implies, is composed of monolithic wall sections which resist applied loadings by their weight and have floors of either the in-situ bedrock, concrete paving, and/or concrete struts. Size and shape of sections should be selected to fit the particular purpose and loading condition. Base widths are made sufficient to prevent sliding and overstressing foundation materials or foundation piles and to ensure that the resultant remains within prescribed areas. Top and intermediate widths are sized to provide a section which will withstand internal wall stresses and at the same time provide space for such installations as filling and emptying systems, anchorages for movable structures, operating equipment, temporary closure structures, the mechanisms, and miscellaneous accessories.

a. Gravity walls. Gravity walls are sized to resist applied loads by weight (see Plates 15 and 16). These walls are usually considered the most economical type of structure from design, construction, and maintenance standpoints, if no unusual foundation problems exist. The supporting media can be soil, bedrock, or pile, with the resulting design being straightforward regardless of the type of foundation. The thick sections of the lock walls lend themselves to watertight construction with low maintenance cost. Construction costs are usually less than for other types of construction due to the simplicity of construction details. As a result of this simplicity, a relatively small amount of skilled labor is required for concrete placement. Other advantages of mass concrete walls are resistance to impact and abrasion of moving barges and ease of maintenance or replacement of damaged sections due to such causes. The disadvantages of these structures are few other than that loads may be heavy in relation to the supporting capacity of the foundation material and possible unequal settlement of adjacent or opposite monoliths may result in damage to or misalignment of the movable structures and the operating machinery.

b. Semigravity walls. Semigravity walls are similar to gravity walls. However, semigravity walls are designed to resist minor tensile forces at horizontal sections and are lightly reinforced. The advantages and disadvantages of these structures are essentially the same as those described for gravity walls.

c. Lock floors. The floors in mass concrete locks are not usually constructed integrally with the walls and are not used as structural members to resist flexural forces. When walls are founded on sound bedrock, the lock chamber floor can usually be excavated to competent rock without any additional treatment. However, if the foundation material is erodible, a paving slab with adequate drainage details to relieve uplift may be required. When individual mass concrete wall monoliths cannot resist lateral forces to obtain the required sliding resistance for lock wall stability, reinforced concrete struts may be added to transfer the lateral load to the opposing wall. The struts may be either continuous for the entire lock chamber length or intermittently spaced to suit the specific project requirements.

4-3. Reinforced Concrete Lock Structure

This term refers to locks that must contain steel reinforcement. The concrete members are flexural members, and reinforcing must be provided to resist tensile stresses. There are numerous instances where certain elements of a lock are made of reinforced concrete. Gravity walls are reinforced at certain thin areas, and the U-frame and

W-frame, as well as cantilevered and counterforted types, are reinforced concrete locks. Approach walls, abutments, areas around culverts, culvert valve recesses, filling and emptying laterals and longitudinals, and numerous other minor parts of most modern gravity locks are constructed of reinforced concrete.

a. U-frame or W-frame. Terms such as "dry dock reinforced concrete" and "bathtub" type have also been used to describe this type lock wall system. This type structure consists of two walls joined by a floor slab to approximate the letter "U." The W-frame is a variation of the U-frame in that it is two U-frame locks set side-by-side approximating the shape of the letter "W." In this manual, the term U-frame will refer to both U-frame and W-frame structures. Details of a U-frame lock are shown on Plate 17.

(1) In a U-frame lock, the walls and floors are designed to act together as a frame and thus are heavily reinforced. Therefore, at high-stress areas No. 14 and No. 18 reinforcing bars are not unusual. Since an intimate knowledge of the foundation properties is required, it is essential that geotechnical and structural engineers maintain close communications throughout the design process. The U-frame may also be founded on rock or steel "H" piling in addition to soil. The advantages of this type lock are lower, more uniform foundation loads, permitting construction on relatively weaker foundations; rigidity against differential settlement or wall rotation; and the capability to unwater the lock chamber for inspection and repair without special foundation treatment for unwatering. The disadvantages of this type of structure may include higher design and construction costs and restricted types of filling and emptying systems.

(2) Advantages of using the W-frame as compared to using two adjacent U-frames include the following:

(a) Lower construction cost through elimination of the joint between the two middle walls.

(b) More efficient resistance to uplift forces since the base is continuous.

(c) Greater potential to use common components for filling and emptying.

Disadvantages of the W-frame lock are a greater concern with thermal effects from continuous concrete placement for the large lock base area and limited experience with construction of this type of lock.

b. Cantilevered or counterforted (buttressed) lock wall. This lock type is one with reinforced concrete retaining walls. Its use should generally be limited to the chamber walls between gate monoliths and to approach walls. The walls may be either cantilevered or counterforted. Spread footings, forming a portion of the lock floor, satisfy the conditions for stability with the keyways preventing sliding and acting as cutoff walls, while at the same time reducing the uplift pressures. The cantilever lock wall dimensions are determined by the size of the filling and emptying system culvert, the pipe gallery, valve and gate recesses, etc., and also must be thick enough to be compatible with the reinforcing steel required. An advantage of this type of construction is that fairly high walls can be provided at a lock location where the foundation properties are poor. There is only one installation of this kind in the United States on a major waterway, e.i., a buttressed wall-type lock named "Little Goose" on the Snake River.

4-4. Tied-Back Concrete

The tied-back concrete wall consists of a reinforced concrete wall which is tied back to a competent material. Ties can be steel reinforcement, prestressing threaded bars, or stranded tendons. The reinforced concrete walls are thinner than other wall types but must be thick enough to contain culverts, galleries, and appurtenances such as floating mooring bitts, check posts, and ladders. Tied-back concrete walls are suitable for use as lock chamber walls and approach walls only and are not adaptable for gate bay monoliths. The project site must have competent material present at the proper elevation for anchoring the tieback. Alternate tiebacks include dead-man-type anchors and battered pile anchors. Details of tied-back concrete walls are shown on Plate 18. Although the tied-back wall design is feasible and savings are possible, attention should be focused on the following issues: provision of corrosion protection for the tendons; preparation of rock surfaces to which the wall is to be anchored; careful alignment of holes in which the tendons are to be anchored; provisions for monitoring the retained stress in the tendons by use of pressure cells; and provisions for restressing the tendons in case of a stress loss. The main advantages of this type wall are the significant cost savings from less rock excavation, less concrete, and a shorter construction time required. The disadvantages include: the requirement for the contractor to excavate to the neat lines shown on the drawings; the difficulty in maintaining the relatively precise alignment of the holes in rock for encasing and anchoring the tendons; the difficulty of providing corrosion protection with the required high degree of confidence; and the necessity to monitor the stress retention in the tendons throughout the life of the structure.

4-5. Steel Sheet Piling

Steel sheet pile lock walls are used only for lock chamber walls and upper and lower approach walls. This type wall is usually used at locations where traffic is not heavy or where a temporary lock is needed. Two basic types of sheet pile walls have been used including anchored tied-back wall and granular filled cellular structures. The first type of wall consists of “Z” piles or arch piles, and the second type consists of straight steel sheet piling. Gate bay monoliths and valve monoliths are usually concrete structures supported on soil or on steel bearing or friction piles. These piling-type walls have been generally used for lifts up to about 15 ft. Sheet pile locks are filled and emptied through sector gates, loop culverts, a combination of sector gates and culverts, valves in miter gates, or special flumes. Details of a sheet pile lock are shown on Plate 19.

a. Anchored and cantilevered (tied-back). Where anchored pile walls are used, a Z-type pile section is often employed for this type of construction because of its high section modulus and interlocking properties. These walls may be provided with a horizontal waler, and tie rods with turnbuckles and dead-man anchorages. Concrete struts may be provided across the floor of the lock chamber to take the reaction of the walls and prevent their inward movement as well as the movement of the lock floor material from around the steel piling. The lock chamber face can be provided with horizontal fenders of timber or steel at levels where tows usually rub. The offsets formed by the Z-piles provide spaces for recessed mooring hooks and ladders. Special anchorages at the top of the lock walls can be provided for check posts to facilitate tying up barges during locking operations. One type of wall consists of piling driven into the foundation material, where stability is gained entirely by passive resistance of the soil below the stabilized groundline. This type of construction is used for retaining walls and is seldom employed where the height of the fill to be retained is in excess of 10 to 15 ft. The other type of construction provides one or more intermediate supports attached to buried anchors in the backfill, with the bottom of the wall restricted by passive resistance. A variation of the latter method for lock walls introduces a system of beams and struts at the floor level. Plate 7 illustrates lock chamber walls of “Z” piling with intermediate supports and lock floor strut systems. EM 1110-2-2906 describes a wall using intermediate tied-back supports and passive resistance from the bottom support.

b. Cellular. Another type pile wall uses steel sheet piling driven to form cells. These cellular walls are filled with sand and gravel and are, in effect, gravity-type retaining walls. Ripping, tearing, or wearing down of the pile interlocks of the cell by barge contact is a concern with cellular structures. Thick steel plates welded onto the cells or onto reinforced concrete panels on the chamber side help to prevent this type of damage. Locks of this type are generally considered temporary with a projected service life of 15 to 20 years. However, O’Brien Lock on the Illinois Waterway was designed as a permanent structure and is in existence today. Layout and details of cellular locks are shown on Plate 20. In the layout, note the additional line of smaller steel sheet pile cells on one side of the lock chamber which form the filling and emptying flume. The culvert valves are located in the concrete gate bay monoliths. Detailed design of cellular sheet pile structure is contained in EM 1110-2-2503.

c. Corrosion. Corrosion is a consideration for steel sheet pile lock walls because some chemical properties of the water or of the soil adjacent to the piling may either promote or accelerate corrosion. The piling and other components are usually used without coatings or cathodic protection of any kind. However, investigation should be made at each individual project to determine the advisability of providing protective coating or cathodic protection. It has been judged in the past that the material loss due to corrosion during the life of the structure will not be detrimental to structural functioning of the piling. It has been observed on existing projects that the worst corrosion occurs at the waterline where constant wetting and drying takes place because of wave action. A protective coating for this area may be advisable.

4-6. Earth Chamber

In a few tidal locks on the intracoastal waterways, earth levees have been used as lock chamber walls with concrete gate bay monoliths. This type of lock is used in low-lift areas. Riprap protection is provided on the levee slopes and on the floor of the lock chamber to prevent scour by towboat propeller action. A continuous timber wall is provided on both sides of the lock chamber. These walls are made up of a series of vertical and battered (braced) wood piling surmounted by a wood walkway and faced with timber walers. Details of this type lock are shown on Plates 13 and 14. Another earth chamber type that may be used for low-lift projects is one which uses a combination of walls and levees for part of the wall height of the portion between gate bays. These walls of concrete or steel sheet piling should be constructed to a height which can accommodate navigation for a high percentage of the time, while the gate bays, gates, and levees are built above the water stages for which lockages are to be provided. When the walls between bays are overtopped, the levees maintain the pool levels along with the gate bays. In this manner, operation can be continued for all stages for which lockages are desired. For this type of construction, wing walls or diaphragms of steel sheet piling filled with earth should be employed on each side of the lock adjacent to both the upper and lower gate bays. Plate 7 shows this type of construction.

4-7. Lock Components

The longitudinal elements of a lock are the chamber walls and their extensions upstream and downstream. Subdivisions of these walls are defined by their position or purpose in the structure as lock chamber walls, upper gate bay walls, lower gate bay walls, culvert intake and discharge walls, upper approach walls, lower approach walls, as well as guard and/or return walls. These subdivisions are further divided into types of monoliths. In the case of a mass concrete lock, the opposing wall segments are normally referred to as separate monoliths, while a U-frame or W-frame monolith will contain both opposing walls and floor (these components are constructed integrally with each other). Lock sills are located across the bottom of each end of the lock chamber to complete closure when the gates are closed. The sills usually extend upward above the lock floor by several feet and are usually designed to withstand the full hydraulic head that would occur when the lock chamber is unwatered.

a. Lock chamber monoliths. The lock chamber monoliths enclose the lock between the upper and lower gate bays. An intermediate wall for the lock chamber is required for dual, side-by-side lock construction or where provision is made for the installation of a second lock at a later date. The chamber monoliths are usually of uniform cross section.

b. Upper and lower gate bay monoliths. The gate bay monoliths include those portions of the lock which house the gate recesses, gate anchorages, gate machinery, and sometimes culvert valves and culvert bulkheads. Plates 6 and 17 show these elements of a lock, as well as the following elements.

c. Bulkhead monoliths. Bulkheads should be provided to unwater the lock chamber or individual gate bays. Bulkhead slots can be placed either in the gate monoliths or in separate monoliths.

d. Culvert-intake and discharge monoliths. Intake monoliths extend immediately upstream beyond the upper gate bays. They provide space for intake ports which lead to the culverts. Discharge monoliths are frequently located immediately downstream of the lower gate bay monoliths and extend far enough to allow the emptying culverts to exit the lock walls.

e. Approach walls. The hydraulic characteristics of the waterway in the vicinity of the upstream and downstream lock approaches and the nature of the traffic dictate what type of special structures are needed to facilitate entrance to and exit from locks and reduce hazards caused by adverse currents. Plates 21 and 22 show various layouts for approach walls. Tows large enough to nearly fill the width of a lock chamber must carefully approach the lock. During adverse current or wind conditions, an approach wall offers a wide, safe target as the operator initiates alignment for entry into the lock. The wall also helps the operator to check the progress of a tow by using check posts or line hooks to correct the alignment. Approach walls also provide mooring spaces for the separated part of tows which are too long to negotiate the lock in one lockage. Thus, approach walls contribute to the safety and speed of lockage. A depiction of various approach wall designs is shown on Plates 23 through 29.

(1) Guide walls. The term guide walls refers to the long extensions of the lock walls, in either the upstream or downstream direction, that are parallel to the lock wall. These walls serve primarily to guide the long tows into the lock and to provide mooring facilities for tows too long to be accomodated in a single lockage. Guide walls can be placed on either the landside, riverside, or both sides of the lock approach, depending upon channel conditions.

(2) Guard walls. Guard walls (see Plate 27) are approach walls designed to minimize entrance or exit difficulties caused by currents. Guard walls also act as barriers to vessel movement in the direction of navigations hazards and serve as the final means of directing the front end of the tow if it is not properly aligned in the direction of the chamber. This measure will help avoid head-on impact with the end of the lock wall. These walls are generally shorter walls that flare away from the

lock approach; however, guide walls that perform these functions can be termed guard walls.

f. Miscellaneous structures.

(1) Return walls. Return walls are retaining walls used to retain the landside lock backfill at the entrance and exit of a lock. Return walls offer several advantages in that they can provide a small docking area out of the lane of traffic at the entrance to the lock and larger operational area near the lock gate area. However, these walls do add significantly to the cost of the project. A typical lock layout with return walls is shown on Plate 8.

(2) Bank tie-in walls. Bank tie-in walls are used to tie the lock structure to higher ground and also serve as a dam to retain the upper pool. These walls may be of a variety of types such as gravity, sheet pile cells, buttresses, inverted tee, etc. The most common type in use today is the inverted tee cutoff wall which is shown on Plate 8.

(3) Separation between locks and dams. If the lock structure and dam are separated, a damming surface must be provided between the two structures.

g. Lock sills. Lock sills are those elements of a lock forming the fixed portion of the damming surface under the service gates or temporary closures. Service gate sills differ from temporary closure sills in that they are used for each lockage, while the latter are in use only when the lock is unwatered for maintenance or during an emergency. The elevation of sill tops in relation to the water surfaces of the upper and lower pools dictates the draft of vessels which can use the lock.

h. Lock floors. The lock floor can be paved, strutted, or left as the natural foundation material as discussed previously in paragraph 4-2*c*.